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Open File Report 6038

Lithostratigraphic Logging of Six Bedrock Boreholes in the Rouge River Valley, Southern Ontario

by

D.K. Armstrong

2000

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Introduction

In April and March, 2000, Ontario Power Generation Inc. (OPG) drilled 6 boreholes into bedrock in the Rouge River valley. The Rouge River is located in the eastern part of the Greater Toronto Area, southern Ontario. The boreholes were sited so as to investigate the possible extension of a bedrock fault observed in an outcrop along the Rouge River (Mohajer et al. 1992; Godin 1999). The Ontario Geological Survey (OGS) was asked by OPG to lithologically log the 6 cores and identify contacts between formations and sub-units encountered in the cores. These data could then be used to help determine if a bedrock fault with significant vertical off-set exists in the area between the boreholes.

This report presents: 1) a lithostratigraphic overview of the bedrock encountered in these cores; 2) lithologic logs for each of the 6 boreholes; 3) geophysical logs of the boreholes, from digital data provided by OPG; 4) structural features encountered in the cores; 5) major element geochemistry of some of the lithologic units; and 6) structure contour maps of the tops of each unit.

The 6 boreholes were drilled in the valley floor, south of Twyn Rivers Drive, on the opposite (west) side of the Rouge River from an outcrop referred to by Mohajer et al. (1992) as "Section 2" and by Godin (1999) as "Site 2" (Figure 1b). The general location of the boreholes is shown in Figure 1a. Specific borehole locations and collar elevations are presented in Table 1.

Bedrock Lithostratigraphy

All 6 of the boreholes intersected Paleozoic bedrock consisting of Upper Ordovician shales and limestones of the Blue Mountain and Lindsay formations. All the holes penetrated, in descending order, the lower part of the Blue Mountain Formation, the Collingwood Member of the Lindsay Formation and the upper part of the lower member of the Lindsay Formation. The stratigraphic nomenclature used in this report is that of Russell and Telford (1983). Descriptions of these formations can also be found in Johnson et al. (1992).

The bedrock in all of the cores was subdivided into 8 correlatable units, numbered 1 through 8, in descending stratigraphic order. The lithologic characteristics and stratigraphic assignment of these 8 units are summarized in Table 2. The top 4 units are assigned to the Blue Mountain Formation. Units 5 and 6 are assigned to the Collingwood Member of the Lindsay Formation. The bottom 2 units, Units 7 and 8, are assigned to the lower member of the Lindsay Formation.

Detailed lithologic logs for each borehole are presented in Appendix 1. A summary of unit (top) depths and elevations and unit thickness in each borehole is presented in Table 3. Lithostratigraphic information for each borehole is graphically summarized and combined with the respective geophysical log in Figures 2 through 7.

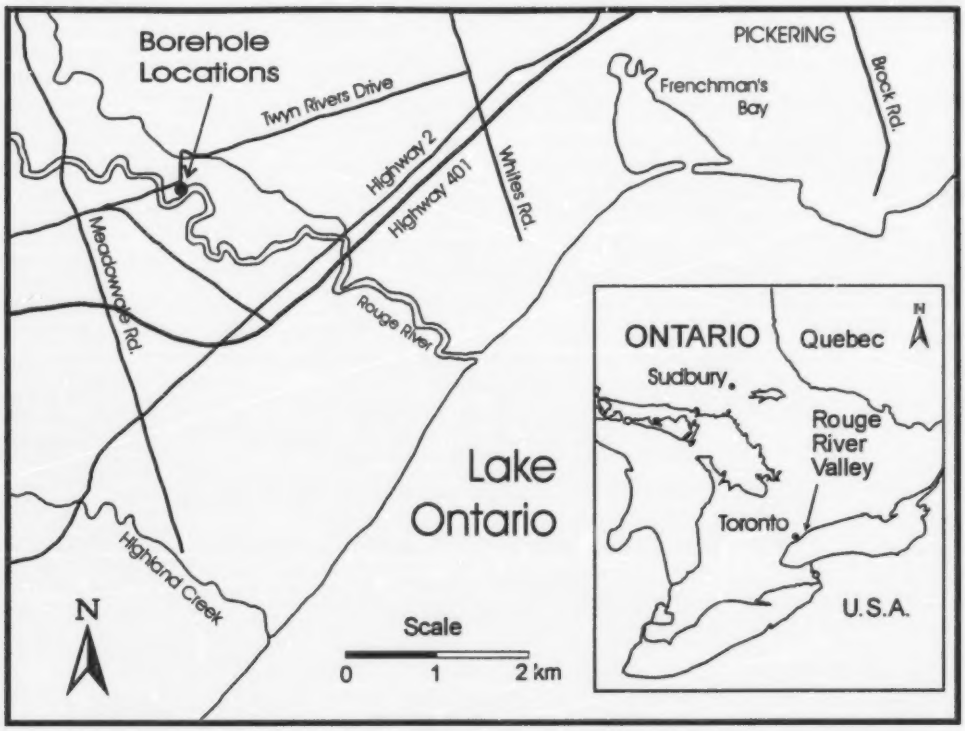

Figure 1a: General location of OPG boreholes in the Rouge River Valley, east of Toronto (map modified after Mohajer et al. 1992).

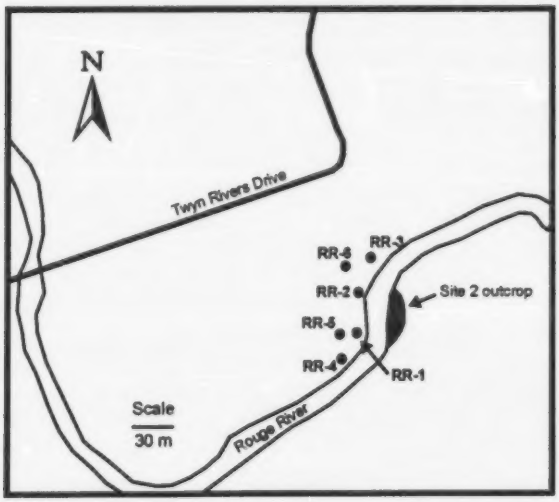

Figure 1b: Specific locations of OPG boreholes.
Site 2 is 'Section 2' of Mohajer et al. (1992).

Table 1: OPG borehole locations and collar elevations.

Hole #	UTM Northing * (m)	UTM Easting * (m)	Collar Elevation (metres above sea level)
RR-1	4852766.4	648217.4	84.73
RR-2	4852798.9	648225.5	84.35
RR-3	4852823.4	648244.2	84.50
RR-4	4852747.2	648200.9	84.64
RR-5	4852769.3	648200.9	83.97
RR-6	4852824.0	648220.4	85.25

* Note: UTM coordinates were determined using the NAD-83 datum; all data supplied by OPG.

Table 2: Lithostratigraphic summary of Rouge River valley boreholes.

Stratigraphic Nomenclature		Unit Number and Lithologic Description
Blue Mountain Formation		Unit 1: green-grey shale with thin interbeds of dark grey shale.
		Unit 2: approximately equal proportions of green-grey shale and dark grey shale.
		Unit 3: green-grey shale with thin, dark grey-black shale interbeds.
		Unit 4: dark grey-brown to black, calcareous, sparsely fossiliferous, slightly to moderately bituminous shale and dark brown, bituminous, very fine-grained limestone.
Lindsay Formation	Collingwood Member	Unit 5: dark brown to black, very fine-grained, moderately fossiliferous bituminous limestone, with sparse, very thin, light brown to white, bioclastic, very fossiliferous limestone interbeds.
		Unit 6: interbedded dark brown to black, very fine-grained, moderately fossiliferous, bituminous limestone, and thin, light brown to white, bioclastic, very fossiliferous limestone.
	lower member	Unit 7: sparsely to moderately fossiliferous, fine-grained, light to medium grey limestone, with thin, dark green-grey to black, slightly bituminous, fossiliferous shale interbeds and partings, and local thin, fossiliferous, limestone interbeds.
		Unit 8: grey, fine-grained, locally argillaceous, fossiliferous, nodular limestone, with dark grey-green, shaly partings and minor thin interbeds.

Table 3: Summary of lithostratigraphic contact depths and elevations. Boreholes are presented in order from southwest to northeast (see Figure 1b).

	RR-4			RR-5			RR-1		
Unit	Depth (m)	Thick-ness (m)	Elev-ation (masl)	Depth (m)	Thick-ness (m)	Elev-ation (masl)	Depth (m)	Thick-ness (m)	Elev-ation (masl)
OB	0.00	2.60	84.64	0.00	2.74	83.97	0.00	3.88	84.73
1	2.60	14.78	82.04	2.74	12.78	81.23	3.88	12.09	80.85
2	17.38	18.81	67.26	15.52	19.83	68.45	15.97	19.93	68.76
3	36.19	6.68	48.45	35.35	6.34	48.62	35.90	6.66	48.83
4	42.87	1.07	41.77	41.69	2.24	42.28	42.56	1.44	42.17
5	43.94	2.41	40.70	43.93	2.73	40.04	44.00	2.90	40.73
6	46.35	1.53	38.29	46.66	0.46	37.31	46.90	0.69	37.83
7	47.88	0.52	36.76	47.12	0.72	36.85	47.59	0.73	37.14
8	48.40	3.07	36.24	47.84	3.06	36.13	48.32	3.25	36.41
EOH	51.47		33.17	50.90		33.07	51.57		33.16

	RR-2			RR-6			RR-3		
Unit	Depth (m)	Thick-ness (m)	Elev-ation (masl)	Depth (m)	Thick-ness (m)	Elev-ation (masl)	Depth (m)	Thick-ness (m)	Elev-ation (masl)
OB	0.00	3.10	84.35	0.00	4.14	85.25	0.00	4.32	84.50
1	3.10	12.33	81.25	4.14	12.61	81.11	4.32	11.00	80.18
2	15.43	19.96	68.92	16.75	19.50	68.50	15.32	19.88	69.18
3	35.39	6.24	48.96	36.25	6.69	49.00	35.20	6.18	49.30
4	41.63	1.57	42.72	42.94	1.16	42.31	41.38	1.82	43.12
5	43.20	3.27	41.15	44.10	3.70	41.15	43.20	3.22	41.30
6	46.47	0.62	37.88	47.80	0.22	37.45	46.42	0.44	38.08
7	47.09	0.59	37.26	48.02	0.34	37.23	46.86	0.56	37.64
8	47.68	3.78	36.67	48.36	3.14	36.89	47.42	4.00	37.08
EOH	51.46		32.89	51.50		33.75	51.42		33.08

Note: OB = overburden; EOH = end of hole; masl = metres above sea level.

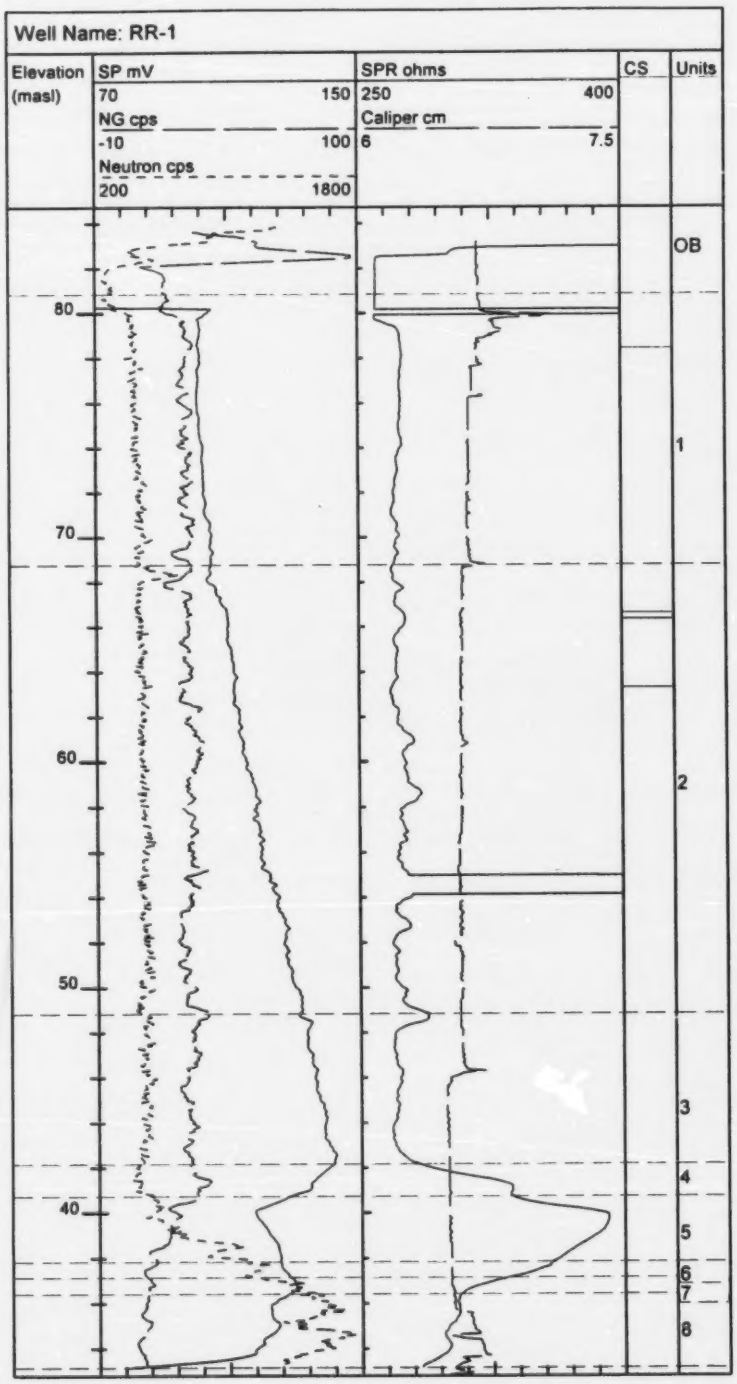

Figure 2: Geophysical, lithostratigraphic unit and clayey seam (CS) logs for borehole RR-1. Clayey seam occurrences plotted as solid lines. See Table 3 for elevations of unit contacts and Table 5 for elevations of clayey seams. See logs in Appendix 1 for unit descriptions. Note: OB = overburden; SP = spontaneous potential; NG = natural gamma; SPR = single point resistivity; cps = counts per second

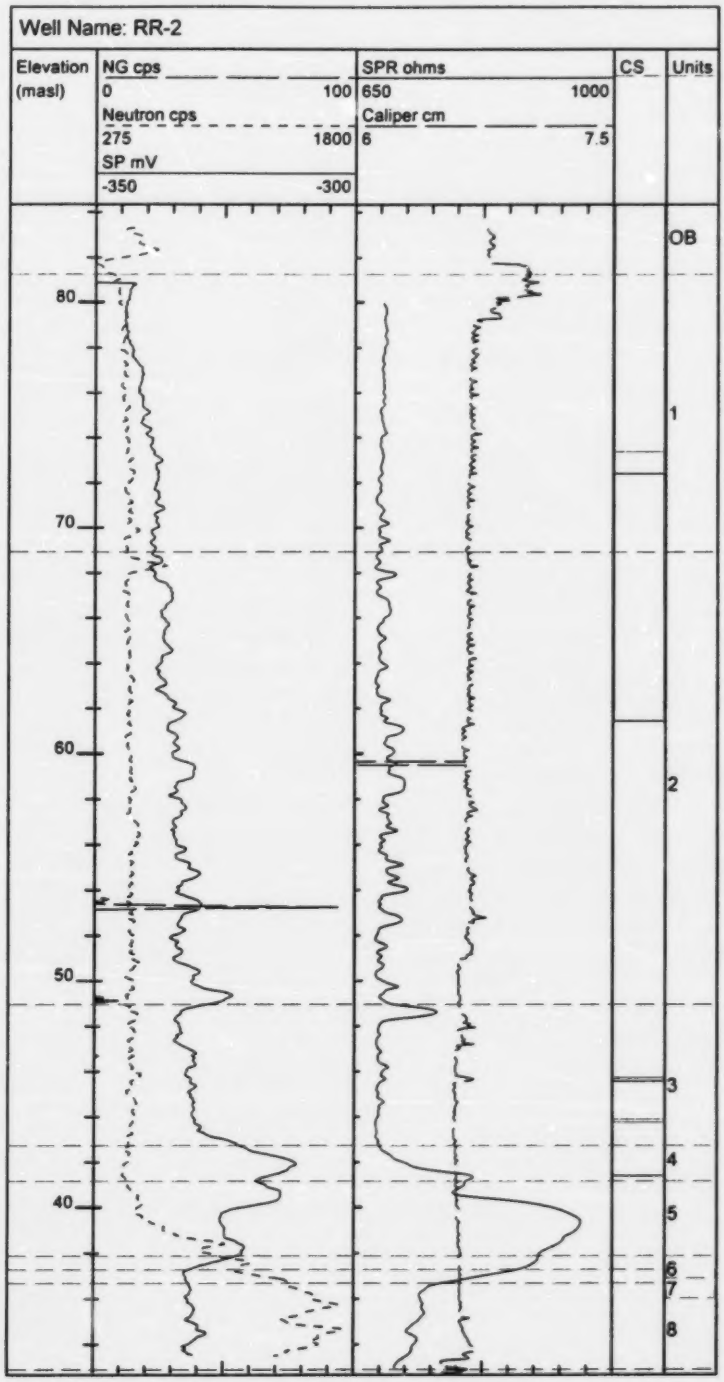

Figure 3: Geophysical, lithostratigraphic unit and clayey seam (CS) logs for borehole RR-2. Clayey seam occurrences plotted as solid lines. See Table 3 for elevations of unit contacts and Table 5 for elevations of clayey seams. See logs in Appendix 1 for unit descriptions. Note: OB = overburden; SP = spontaneous potential; NG = natural gamma; SPR = single point resistivity; cps = counts per second

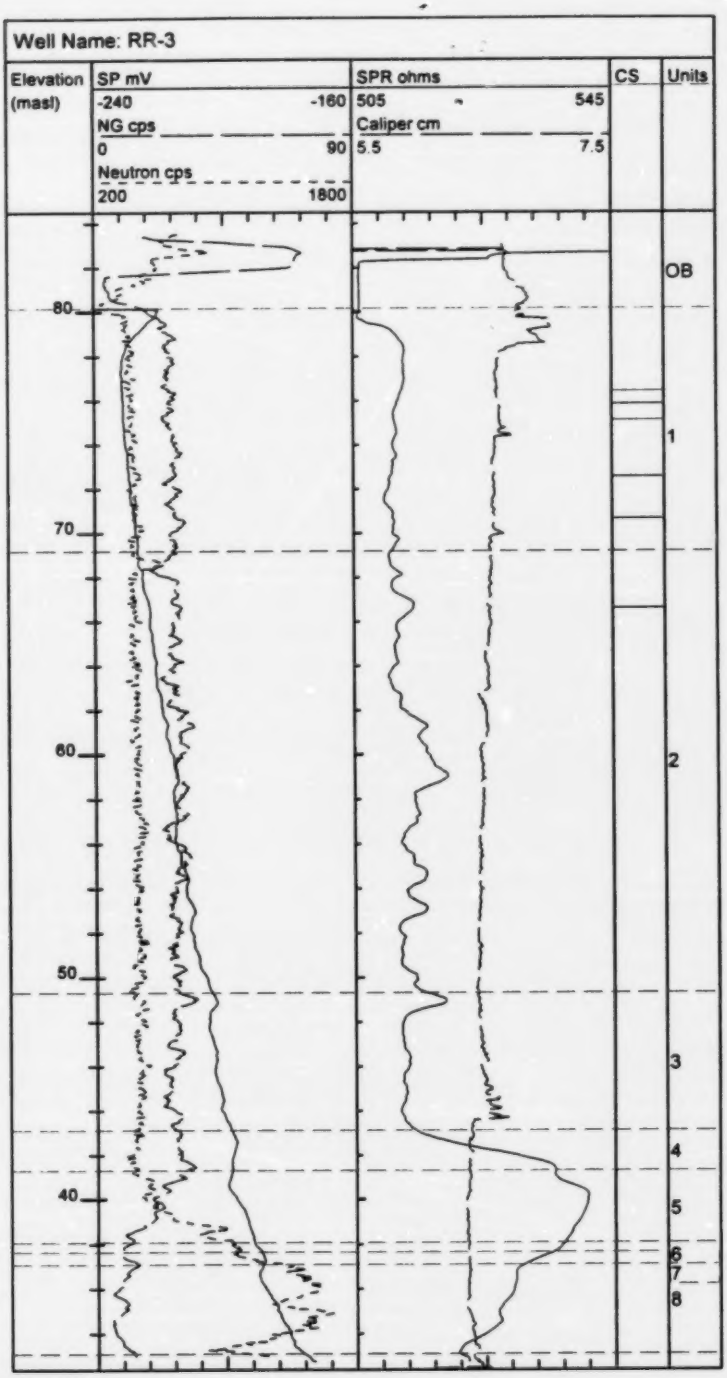

Figure 4: Geophysical, lithostratigraphic unit and clayey seam (CS) logs for borehole RR-3. Clayey seam occurrences plotted as solid lines. See Table 3 for elevations of unit contacts and Table 5 for elevations of clayey seams. See logs in Appendix 1 for unit descriptions. Note: OB = overburden; SP = spontaneous potential; NG = natural gamma; SPR = single point resistivity; cps = counts per second

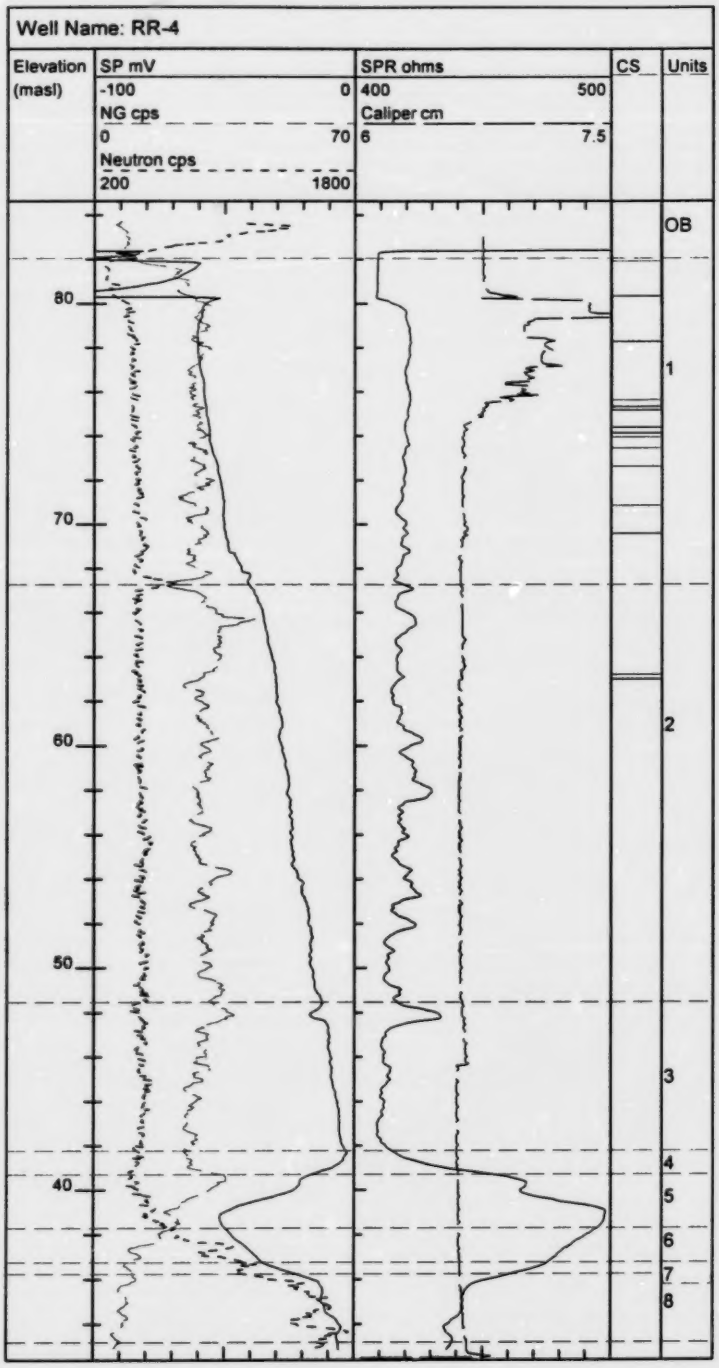

Figure 5: Geophysical, lithostratigraphic unit and clayey seam (CS) logs for borehole RR-4. Clayey seam occurrences plotted as solid lines. See Table 3 for elevations of unit contacts and Table 5 for elevations of clayey seams. See logs in Appendix 1 for unit descriptions. Note: OB = overburden; SP = spontaneous potential; NG = natural gamma; SPR = single point resistivity; cps = counts per second

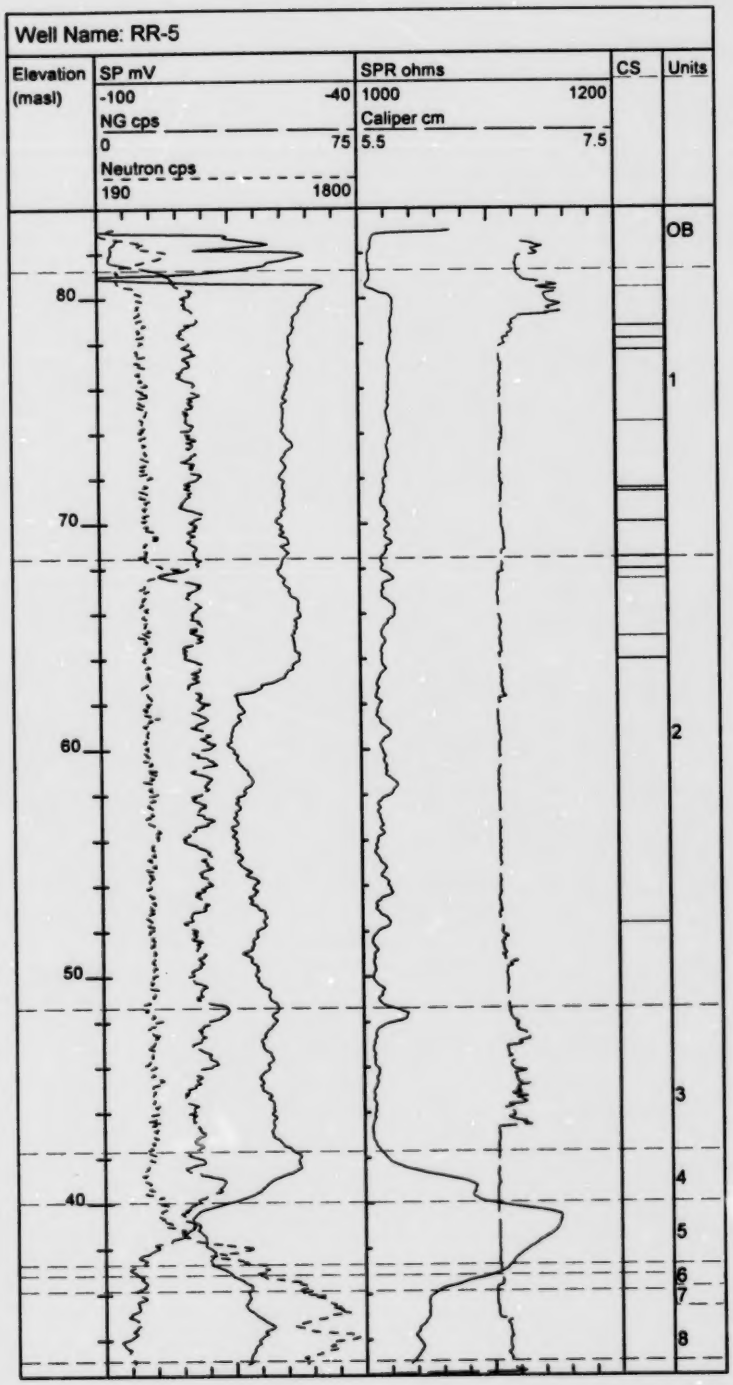

Figure 6: Geophysical, lithostratigraphic unit and clayey seam (CS) logs for borehole RR-5. Clayey seam occurrences plotted as solid lines. See Table 3 for elevations of unit contacts and Table 5 for elevations of clayey seams. See logs in Appendix 1 for unit descriptions. Note: OB = overburden; SP = spontaneous potential; NG = natural gamma; SPR = single point resistivity; cps = counts per second

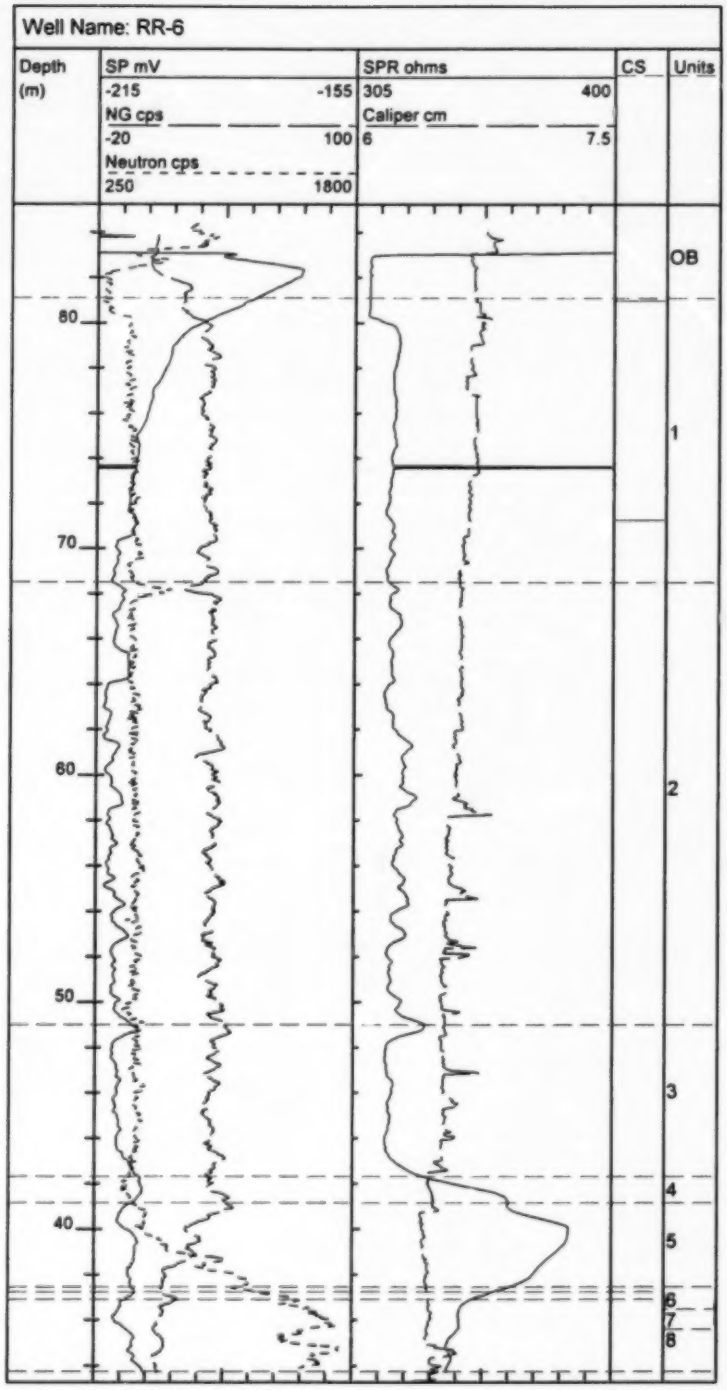

Figure 7: Geophysical, lithostratigraphic unit and clayey seam (CS) logs for borehole RR-6. Clayey seam occurrences plotted as solid lines. See Table 3 for elevations of unit contacts and Table 5 for elevations of clayey seams. See logs in Appendix 1 for unit descriptions. Note: OB = overburden; SP = spontaneous potential; NG = natural gamma; SPR = single point resistivity; cps = counts per second.

LITHOLOGIC UNIT DESCRIPTIONS

Unit 1 consists of green-grey shale with thin (up to 15 cm) interbeds of dark grey shale. Typically, the top 0.5 m is weathered and clayey. Weathered, clayey horizontal seams up to 10 cm thick occur as low as 7.5 m below the bedrock surface. Unit 1 ranges from 11.00 to 14.78 m in thickness, averaging 12.60 m. Its thickness in the cores is largely controlled by post-depositional erosion. Unit 1 is unconformably overlain by Quaternary age unconsolidated sediments. The Quaternary sediments were not cored and thus are not described herein.

Unit 2 consists of approximately equal proportions of green-grey shale and dark grey shale. Dark beds tend to be thinner than light beds, however, they do range up to 1 m thick, especially towards the base of the unit. Unit 2 ranges from 18.81 to 19.96 m in thickness, averaging 19.65 m. It generally thickens to the southwest.

Unit 3 is similar to Unit 1, consisting of green-grey shale with thin, dark grey-black shale interbeds. Dark beds typically represent less than 10% of the unit, are less than 5 cm thick and locally are slightly calcareous. Unit 3 ranges from 6.18 to 6.69 m thick, averaging 6.47 m.

Unit 4 consists of dark grey-brown to black, calcareous, sparsely fossiliferous, slightly to moderately bituminous shale and dark brown, bituminous, very fine-grained limestone. Pyrite blebs (small nodules) and pyritized fossils occur locally. Fossils include flattened nautiloids, and trilobite pieces. This unit appears to be transitional in character between the overlying Unit 3 and underlying Unit 5. Unit 4 ranges from 1.07 to 2.24 m in thickness and averages 1.55 m.

Unit 5 consists of dark brown to black, very fine-grained, moderately fossiliferous bituminous limestone, with sparse, very thin, light brown to white, bioclastic, very fossiliferous limestone interbeds. Thin light bioclastic interbeds contain shelly and other fossil debris (i.e., fossil "hash"). Unit 5 ranges from 2.41 to 3.70 m in thickness, and averages 3.04 m. It thickens from south to north. This unit represents the upper part of the Collingwood Member of the Lindsay Formation.

Unit 6 consists of interbedded dark brown to black, very fine-grained, moderately fossiliferous, bituminous limestone, and thin, light brown to white, bioclastic, very fossiliferous limestone. These rock types are similar in character to those in Unit 5, however, the light bioclastic beds are thicker (up to 4 cm) and more abundant in Unit 6. Unit 6 ranges from 0.22 to 1.53 m in thickness, with an average of 0.66 m. The basal contact of Unit 6 is sharp and undulatory to irregular over the underlying unit.

Unit 7 consists of sparsely to moderately fossiliferous, fine-grained, light to medium grey limestone, with thin, dark green-grey to black, slightly bituminous, fossiliferous shale interbeds and partings, and local thin, fossiliferous, limestone interbeds. Limestone beds are up to 20 cm thick and range from tabular with sharp contacts to undulatory or nodular with diffuse contacts. Some limestone beds, especially the topmost one, contain irregular

colour mottling, possibly after bioturbation. Shale beds are up to 4 cm thick. The basal contact is gradational and placed at the base of the lowest significant shale bed. Unit 7 ranges from 0.34 to 0.73 m thick, and averages 0.58 m.

Unit 8 consists of grey, fine-grained, locally argillaceous, fossiliferous, nodular limestone, with dark grey-green, shaly partings and minor thin interbeds. The topmost bed of this unit, in a few of the cores, contains a small (up to 5 cm long) v-shaped vertical fracture filled with coarse calcite.

GEOCHEMISTRY

A suite of samples from borehole RR-2 representing Units 1 through 6 (except Unit 3) were submitted to the Ontario Geoscience Laboratories, for major element analysis by X-ray fluorescence, and for carbon and sulphur analysis by IR spectroscopy. Data from these analyses (presented in Table 4) confirm the highly calcareous (i.e., higher CaO and CO_2 values) nature of the Collingwood Member, as compared to the overlying Blue Mountain Formation shales. In addition, significantly elevated CO_2 and S values, and slightly elevated LOI values, suggest that the dark grey shale beds in the Blue Mountain Formation have higher organic matter content relative to the green-grey shale beds.

GEOPHYSICAL LOGS

Selected geophysical logs for each borehole are presented in Figures 2 to 7. Geophysical logs illustrate general patterns related to lithologic characteristics, such as in the decrease in natural gamma (NG log) response, and increase in resistivity (SPR log) in the transition from the Blue Mountain Formation into the Collingwood Member. These responses reflect a decrease in siliciclastic clay (i.e., shale) content and increase in carbonate content downwards into the Lindsay Formation.

In addition, patterns or specific spikes in geophysical logs are sometimes coincident with lithologically identified unit contacts, and thus are useful in correlating units between boreholes. For example, the contact between Units 1 and 2 is generally coincident with a natural gamma (NG) low just above a natural gamma spike in most of the boreholes.

Structural Geology

FEATURES OBSERVED IN THE CORES

Horizontal clayey seams occur in the upper parts of most of the cores. Table 5, prepared from data supplied by OPG, presents the elevations and thickness of clayey seams intersected in each of the 6 cores. The locations of these seams are also plotted in Figures 2 to 7. Most of these seams contain green or grey clay which appears to have been

Table 4: Geochemistry of samples representing lithologic units in OPG borehole RR-2 (all results in weight percent).

OGS Sample #	Depth from (m)	Depth to (m)	Unit #	Sample Description	SiO2	Al2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	TiO2	Fe2O3	LOI	Total	CO2	S
00DKA-200A	7.50	7.60	1	green-grey shale	53.82	17.54	0.13	3.16	3.16	0.61	4.50	0.25	0.85	6.86	8.43	99.30	3.72	0.58
00DKA-200E	9.00	9.03	1	dark grey shale	54.79	16.96	0.08	2.94	2.19	0.65	4.35	0.25	0.79	6.92	8.89	98.81	8.44	1.06
00DKA-200B	22.50	22.64	2	dark grey shale	53.74	16.86	0.08	2.74	3.31	0.69	4.32	0.28	0.79	6.48	9.17	98.47	10.80	0.98
00DKA-200C	22.94	23.05	2	brown clay, in horizontal seam	53.44	16.91	0.08	2.76	3.31	0.71	4.26	0.30	0.79	6.68	9.03	98.28	8.86	1.10
00DKA-200D	34.31	34.50	2	green-grey shale	56.88	16.51	0.12	3.23	2.71	0.82	4.26	0.14	0.85	6.03	8.05	99.60	4.79	0.30
00DKA-200F	41.87	42.00	4	dark brown, bituminous, calcareous shale	51.21	15.60	0.08	2.75	4.86	0.72	3.86	0.21	0.74	7.31	9.28	96.61	13.40	1.96
00DKA-200G	44.84	45.00	5	black bituminous limestone/ shale, fissile	28.56	8.20	0.06	1.92	25.37	0.45	2.09	0.64	0.36	4.08	24.91	96.64	35.00	1.38
00DKA-200H	46.50	46.63	6	dark brown bituminous limestone with white shelly, fossiliferous hash limestone beds	17.20	4.84	0.04	1.90	38.02	0.27	1.30	0.28	0.19	2.05	33.02	99.11	35.60	0.45
				detection limits:	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	n/a	0.03	0.01

Table 5: Clayey seam occurrences in boreholes, from data supplied by OPG. Boreholes are presented in order from southwest to northeast (see Figure 1b).

RR-4			RR-5			RR-1		
Elev-ation (masl)	Depth (m)	Thick-ness (mm)	Elev-ation (masl)	Depth (m)	Thick-ness (mm)	Elev-ation (masl)	Depth (m)	Thick-ness (mm)
81.92	2.72	20	80.45	3.52	10	78.44	6.29	10
80.34	4.30	30	78.73 to 78.17	5.24 to 5.80	16 @ 1 - 5 mm	66.61	18.12	1
78.28	6.36	2	77.67	6.30	5	66.35	18.38	1
75.77	8.87	10	74.50	9.47	1	63.29	21.44	5
75.64 to 75.34	9.00 to 9.30	10 @ 1 - 2 mm	71.55 to 71.40	12.42 to 12.57	7 @ 1 - 2 mm			
75.18	9.46	2	70.04	13.93	3			
74.40	10.24	2	68.50	15.47	6			
74.14 to 73.94	10.50 to 10.70	5 @ 1 - 2 mm	68.47	15.50	2			
73.45	11.19	2	67.96	16.01	1			
72.62	12.02	2	67.52	16.45	3			
70.84	13.80	2	67.50	16.47	2			
69.59	15.05	1	64.96	19.01	1			
63.20	21.44	10	63.96	20.01	5			
62.99	21.65	10	52.33	31.64	5			

RR-2			RR-6			RR-3		
Elev-ation (masl)	Depth (m)	Thick-ness (mm)	Elev-ation (masl)	Depth (m)	Thick-ness (mm)	Elev-ation (masl)	Depth (m)	Thick-ness (mm)
73.39	10.96	1	80.99	4.26	80	76.43 to 75.86	8.07 to 8.64	9 @ 1 - 6 mm
72.42	11.93	2	71.27	13.98	2	75.12	9.38	1
61.46	22.89	5				72.56	11.94	2
61.35	23.00	120*				70.66	13.84	12
45.72	38.63	3				66.61	17.89	2
45.58	38.77	3						
43.88	40.47	1						
43.76	40.59	2						
41.40	42.95	5						

Note: * indicates associated natural gas occurrence; masl = metres above sea level.

derived from *in-situ* weathering of the host shale. Detailed clay mineralogical analysis of clayey seam and host shale materials should be done to confirm this hypothesis.

Sub-vertical fractures occur at various elevations in boreholes RR-2 and RR-3 (see logs in Appendix 1 for locations). These fractures are very thin (< 1 mm) and typically coated with calcite. They do not exhibit obvious signs of brecciation or of weathering and are likely joints.

Borehole RR-2 intersected a 12 cm thick horizontal seam at a depth (top) 23.00 m (elevation 61.46 masl) that is filled with brown clay (i.e., different material than that occurring in the clayey seams) and associated with an occurrence of natural gas. There appears to be no relationship between this horizontal seam and sub-vertical fractures encountered in RR-2.

STRUCTURE CONTOUR MAPS

The unit contact elevation data summarized in Table 3 were used to construct structure contour maps of the tops of each unit (Figures 8 to 15). Except for local minor variations, most of the inter-unit contacts dip gently to the southwest at a rate ranging from approximately 10 to 25 m per km.

Irregularity in the structure contour pattern for the top of Unit 1 (Figure 8) may be due, in part, to post-depositional erosion. This unit is unconformably overlain by Quaternary glacial sediments. However, a change in slope in the surface of Unit 2 (Figure 9) in the vicinity of borehole RR-1, suggests that there may be a structural control to this irregularity. Similar patterns are not observed in lower units (e.g., Figure 10), so if a fault exists, it appears to diminish with depth.

Conclusions and Recommendations

1. No obvious faults (e.g., brecciated core) were intersected by any of the 6 boreholes.

2. Only minor vertical off-sets of bedrock strata are inferred by structure contour maps of unit contacts and these are largely confined to the uppermost 2 units (i.e., down to a depth of approximately 17 m below surface or an elevation of 67 masl).

3. Horizontal clayey seams likely represent *in-situ* weathering of host shale, although mineralogical analysis of these materials is required to confirm this.

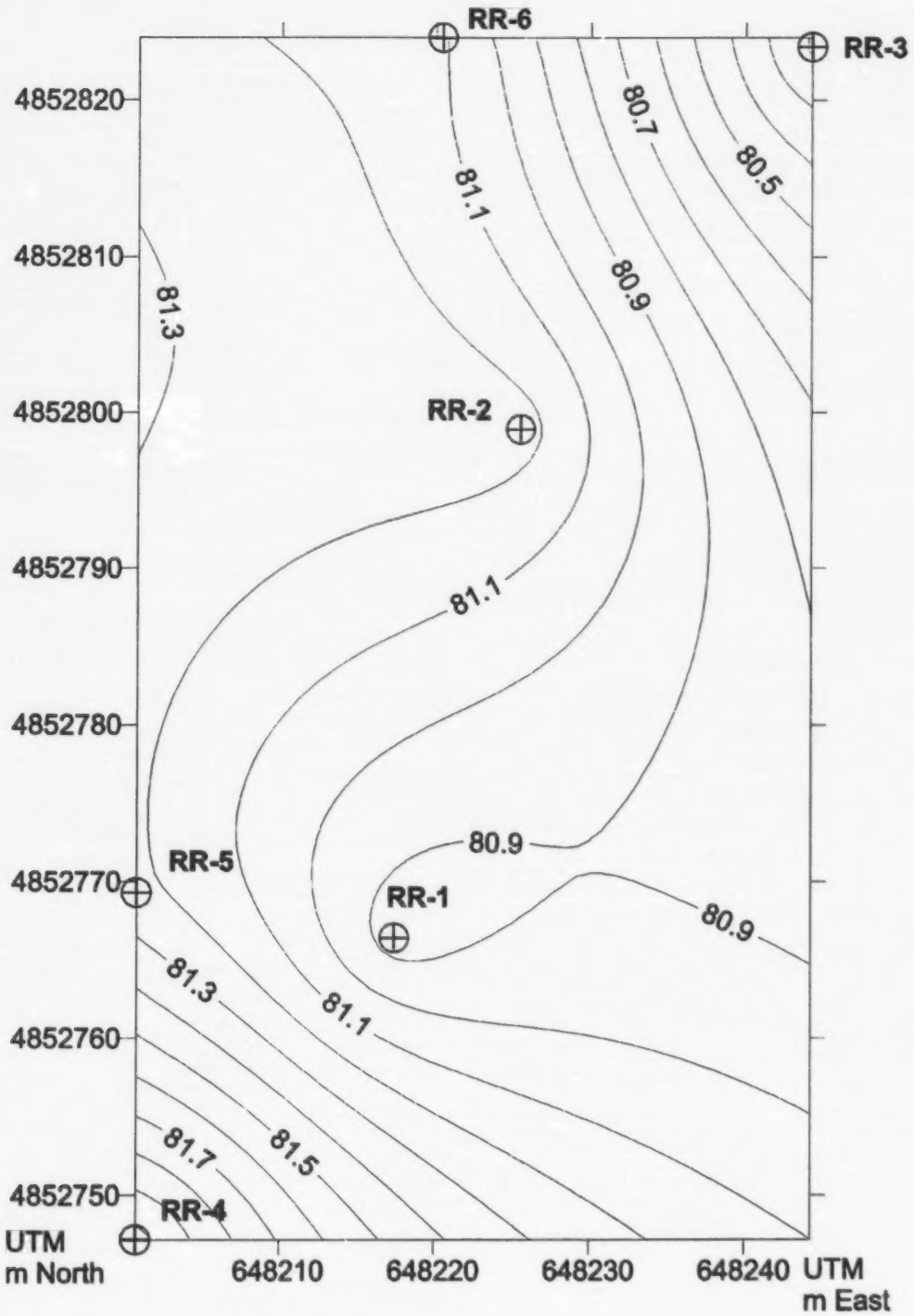

Figure 8: Structure contour on top of Unit 1 (contour intervals in metres above sea level). Borehole locations are plotted as circled crosses.

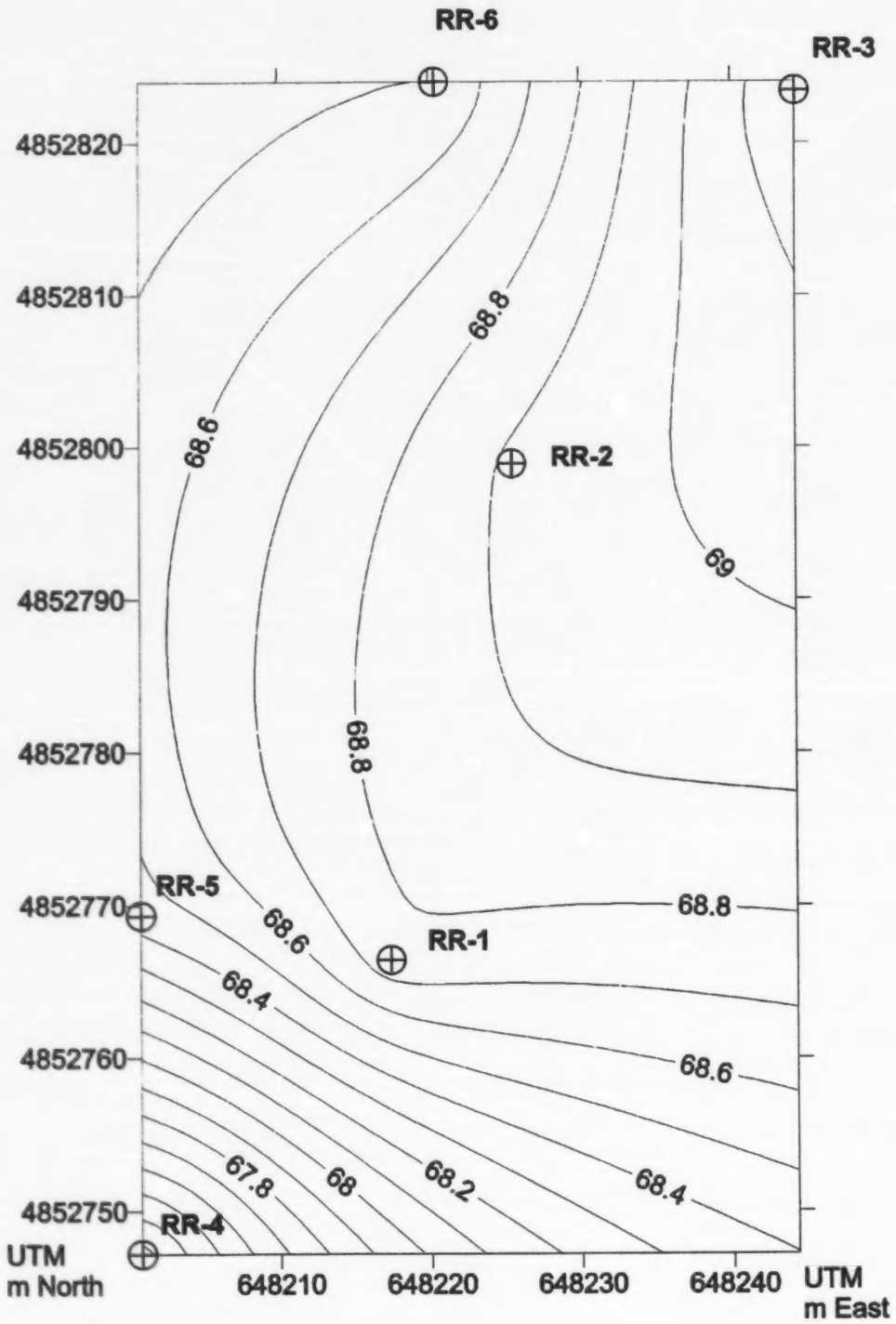

Figure 9: Structure contour on top of Unit 2 (contour intervals in metres above sea level). Borehole locations are plotted as circled crosses.

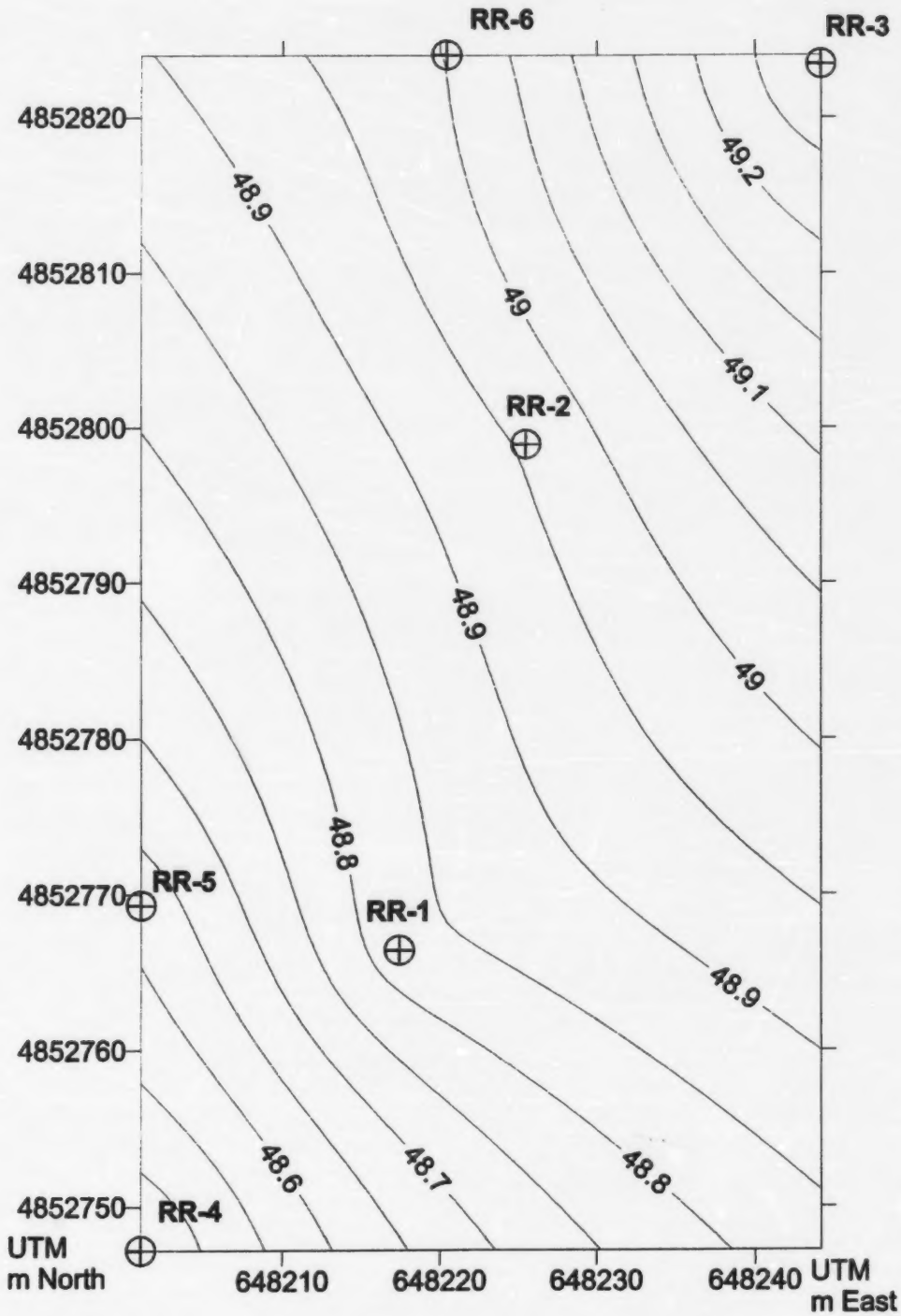

Figure 10: Structure contour on top of Unit 3 (contour intervals in metres above sea level). Borehole locations are plotted as circled crosses.

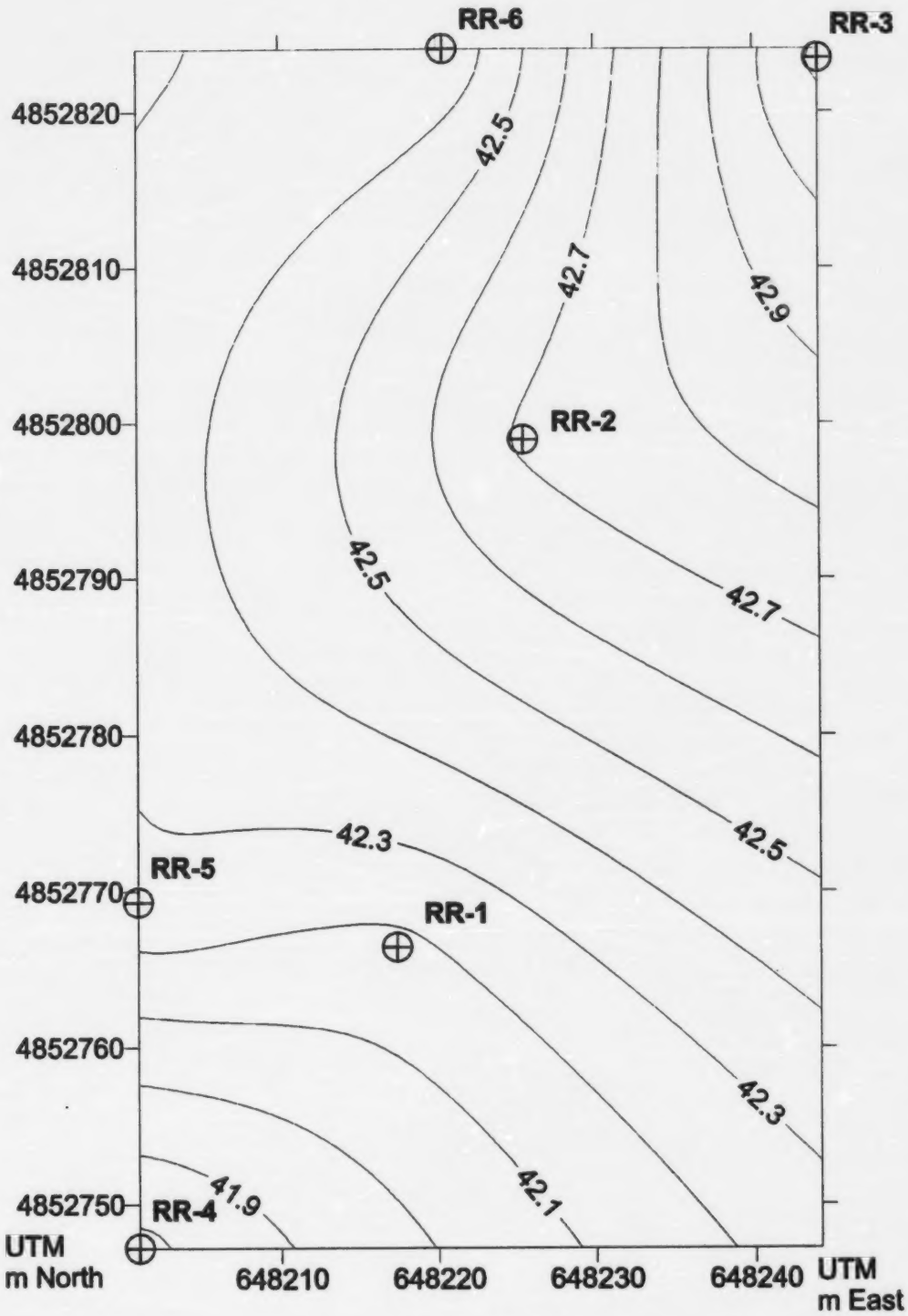

Figure 11: Structure contour on top of Unit 4 (contour intervals in metres above sea level). Borehole locations are plotted as circled crosses.

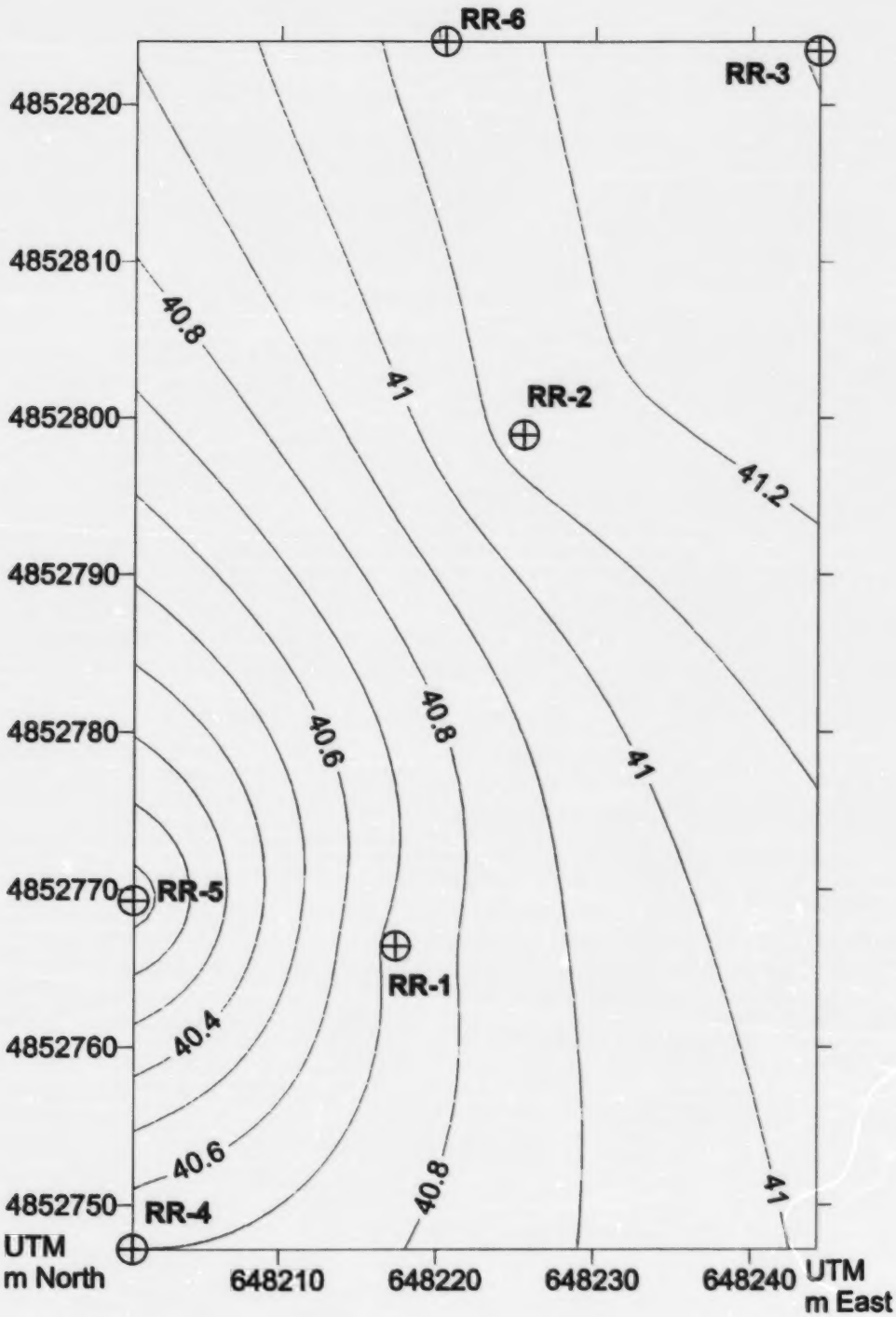

Figure 12: Structure contour on top of Unit 5 (contour intervals in metres above sea level). Borehole locations are plotted as circled crosses.

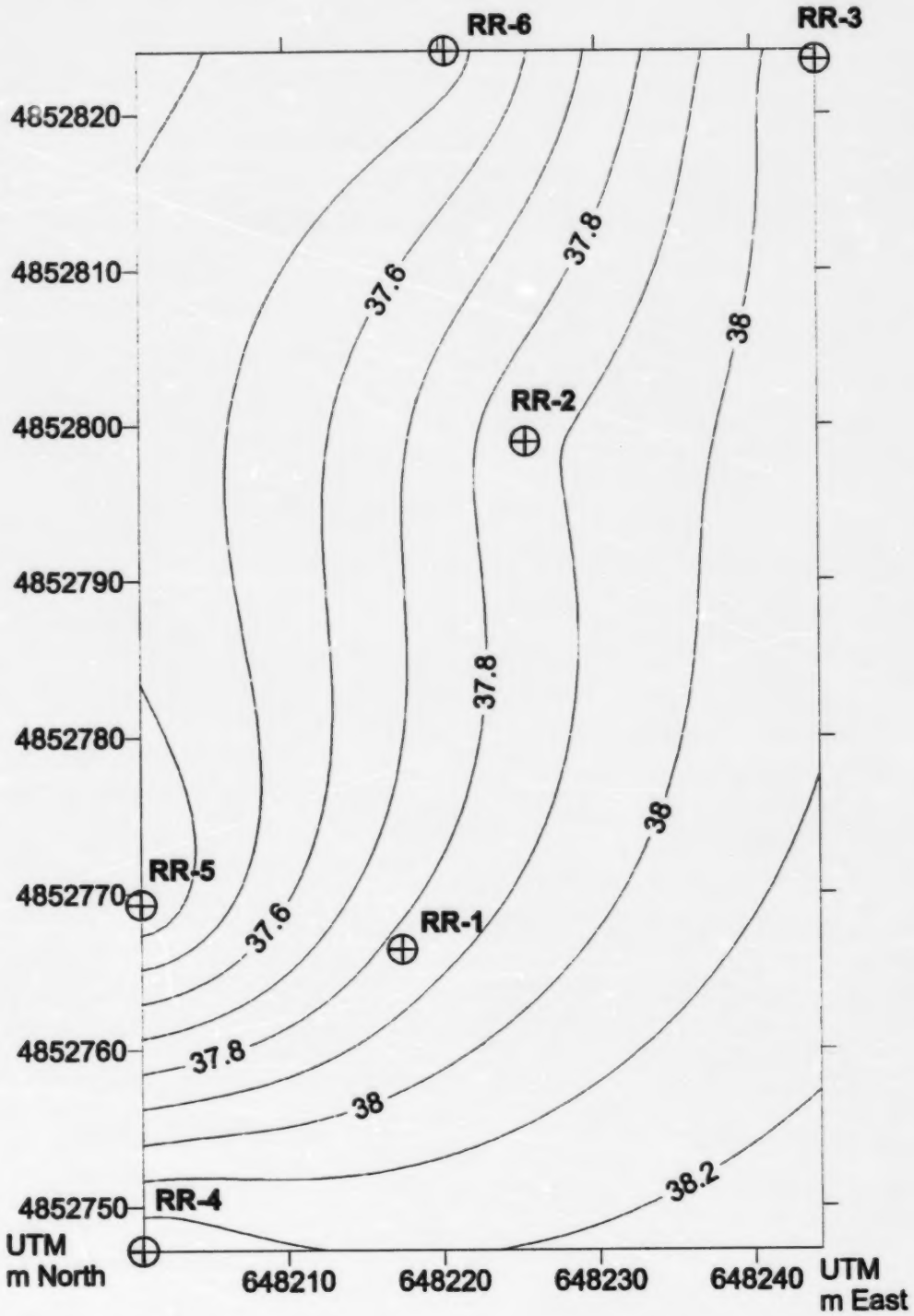

Figure 13: Structure contour on top of Unit 6 (contour intervals in metres above sea level). Borehole locations are plotted as circled crosses.

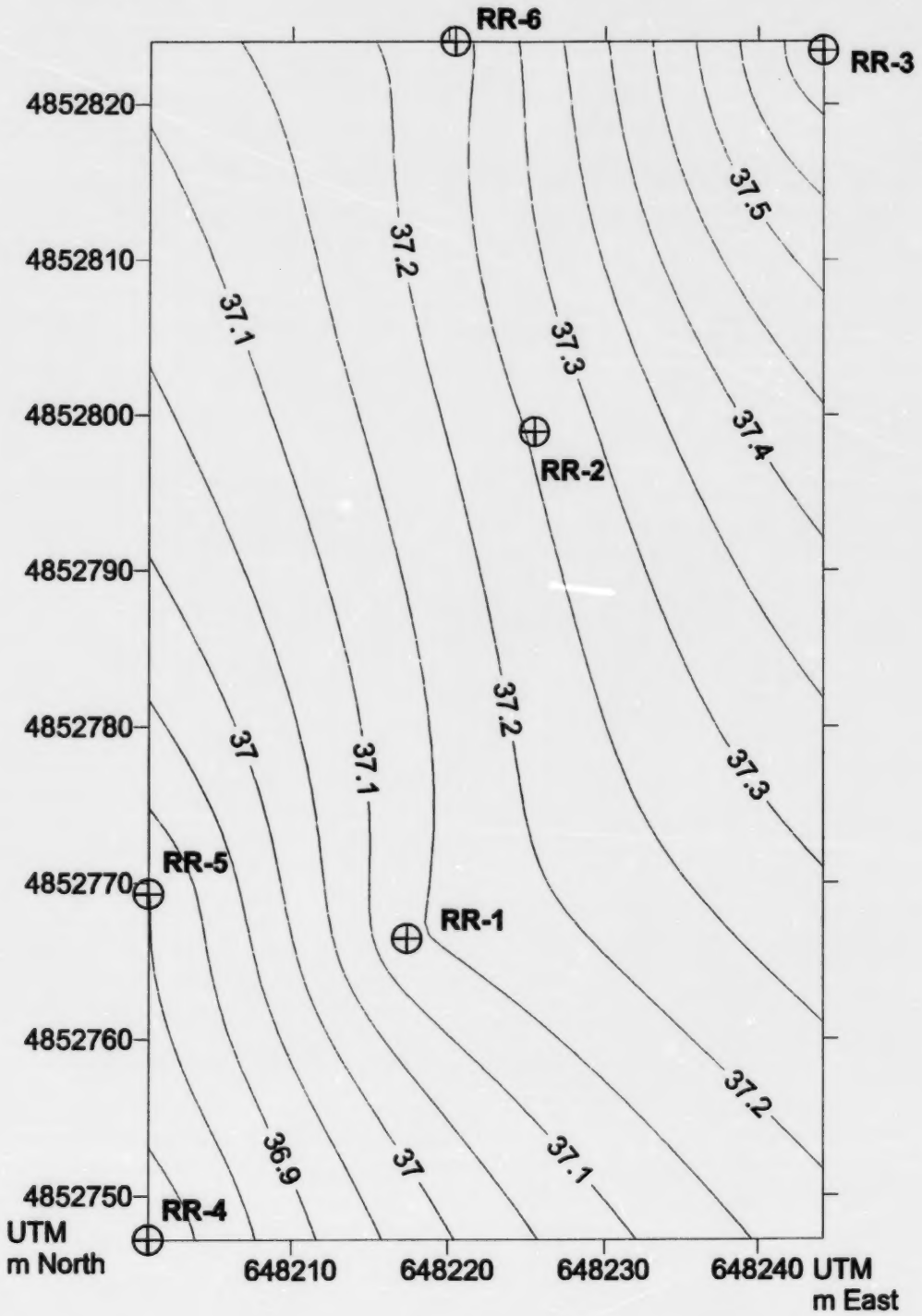

Figure 14: Structure contour on top of Unit 7 (contour intervals in metres above sea level). Borehole locations are plotted as circled crosses.

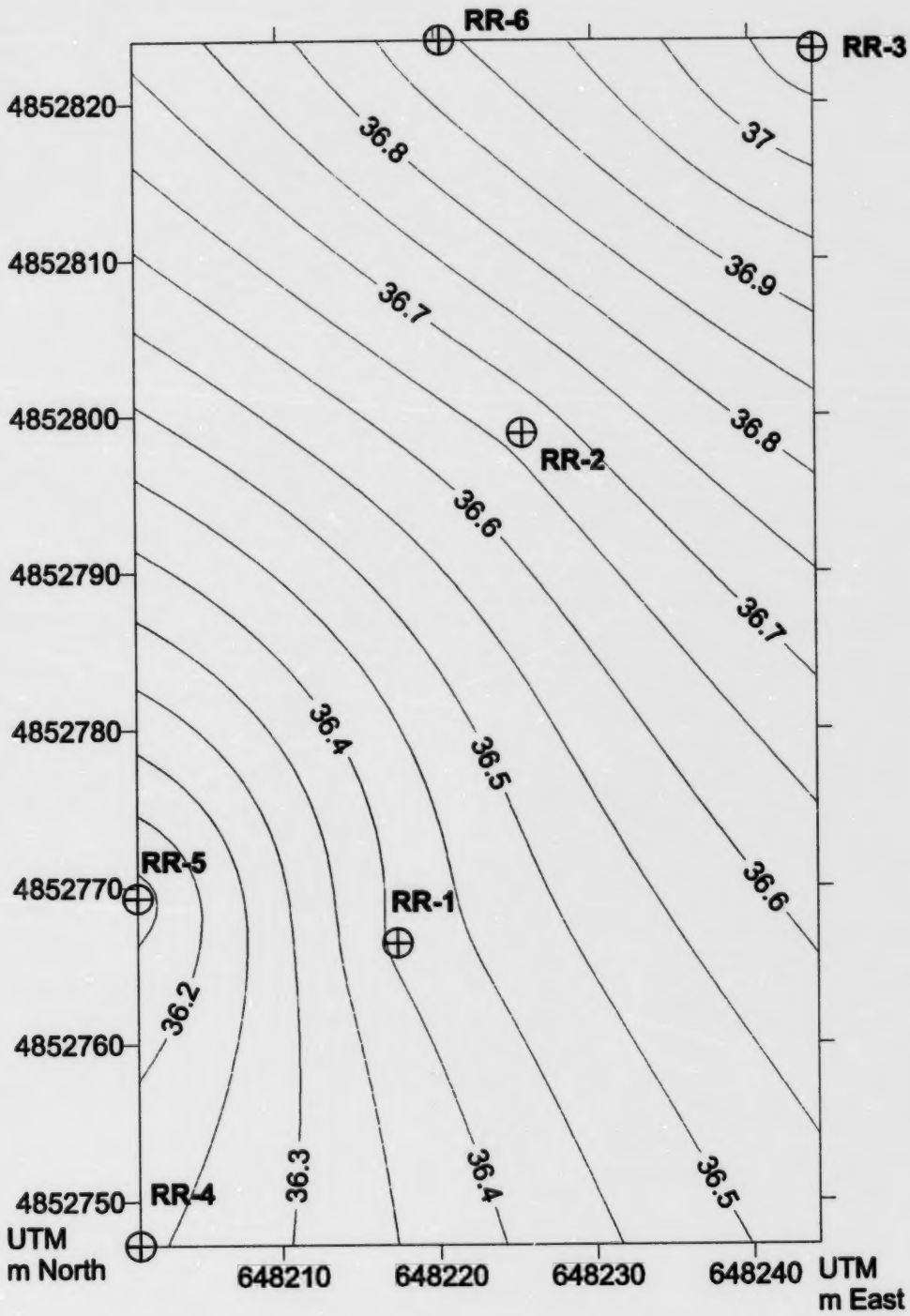

Figure 15: Structure contour on top of Unit 8 (contour intervals in metres above sea level). Borehole locations are plotted as circled crosses.

Acknowledgements

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APPENDIX 1

Detailed lithologic logs for boreholes RR-1, RR-2, RR-3, RR-4, RR-5, RR-6.

Borehole #: RR-1	Location: Rouge River Valley UTM co-ordinates: 648217.4 mE 4852766.4 mN
Date Drilled: April 5 – 7, 2000	Date Logged: May 9, 2000
Drilled by/for: Ontario Power Generation	Logged by: Derek Armstrong (OGS)
Collar Elevation: 84.73 m	Total Depth: 51.57 m

Lithologic Unit Descriptions:

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
0	0	3.88	Quaternary	Overburden – not sampled.
1	3.88	15.97	Blue Mountain	Shale: grey shale, with dark grey-black shale interbeds. - approximately 10% dark beds - top 30 cm is weathered; rough clayey appearance. - similarly weathered bands or clay seams continue down to ~ 6 m – some thin sparse clay seams below this.
2	15.97	35.90	Blue Mountain	Shale: interbedded grey and dark grey-black shale (~50/50). - beds typically 10 to 20 cm thick. - dark beds tend to be thinner. - dark beds at base is 70 cm thick. - locally slightly calcareous below ~ 25 m (tends to be darker beds)
3	35.90	42.56	Blue Mountain	Shale: grey shale, with thin dark grey-black to dark grey-brown shale beds. - dark beds are 1 – 12 cm thick, averaging 2 – 5 cm. - gradational basal contact.
4	42.56	~44.00	Blue Mountain	Shale: black slightly calcareous, slightly to moderately bituminous shale. - occasional pyrite blebs/nodules (e.g., 0.5 x 2.5 cm (wide) nodule @ 42.79 m). - some nautiloids (flattened) and trilobite fragments (e.g., large trilobite tail @ 44.02 m; large nautiloid @ 43.98 m). - gradational basal contact.

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
5	~44.00	46.90	Lindsay Formation - Collingwood Mb.	Shale and Limestone: dark brown and black, bituminous, calcareous shale and limestone, with sparse, thin (1 – 2 mm) light brown to white fossiliferous beds. - fossiliferous beds are thicker and more abundant towards the base of the unit. - trilobites and nautiloids occur on most bedding planes. - sparse, small crinoid ossicles, generally more abundant with depth and in fossiliferous beds; fossiliferous beds also contain small brachiopods. - less shaly and more massive with depth.
6	46.90	47.59	Lindsay Formation - Collingwood Mb.	Bituminous limestone: interbedded dark brown-black, very fine-grained, bituminous limestone and light brown to white very fossiliferous limestone (< 25%). - light fossiliferous beds up to 2 cm thick, but typically < 1 cm thick. - light fossiliferous beds contain abundant small brachiopods, trilobites, and crinoid fragments. - sharp base at top of thicker light brown fossiliferous bed.
7	47.59	48.32	Lindsay Formation – lower member	Limestone and shale: sparsely fossiliferous, light grey, very fine- to fine-grained limestone, dark green-grey shale beds, and a few thin, very fossiliferous limestone beds. - shale beds are 2 – 4 cm thick. - limestone beds are 5 – 10 cm thick, and are undulatory to nodular. - topmost 4 cm is very fossiliferous bed. - gradational basal contact – placed at lowest "solid" shale bed.
8	48.32	51.57 (end of hole)	Lindsay Formation – lower member	Limestone and minor shale: nodular grey fossiliferous limestone with dark green-grey shale partings and thin beds (< 2 cm thick). - ranges from argillaceous, fossiliferous limestone (e.g., 48.75 – 49.10 m) to distinct limestone beds with shaly partings and interbeds. - basal 8 cm is mostly shale with small (~ 5 cm) limestone nodule.

Borehole #: RR-2	Location: Rouge River Valley UTM co-ordinates: 648225.5 mE 4852798.9 mN
Date Drilled: April 10 – 13, 2000	Date Logged: May 10, 2000
Drilled by/for: Ontario Power Generation	Logged by: Derek Armstrong (OGS)
Collar Elevation: 84.35 m	Total Depth: 51.46 m

Lithologic Unit Descriptions:

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
0	0	3.10	Quaternary	Overburden – not sampled.
1	3.10	15.43	Blue Mountain	Shale: green-grey shale, with thin dark grey-black shale interbeds. - top 50 cm is weathered. - a few thin clayey seams below 50 cm.
2	15.43	35.39	Blue Mountain	Shale: interbedded grey and dark grey shale. - dark shale beds at: 15.43 – 15.85 m; 16.58 – 17.52 m; 22.21 – 22.82 m; 23.19 – 23.68 m; 24.42 – 25.36 m, 29.31 – 29.81 m; 30.60 – 31.30m; 34.68 – 35.39 m. - brown clay seam @ 22.94 – 23.05 m – produced natural gas.
3	35.90	41.63	Blue Mountain	Shale: green-grey shale, with thin dark grey-black shale interbeds. - gradational basal contact.
4	41.63	~43.20	Blue Mountain	Shale and limestone: dark brown, bituminous limestone and dark grey-black calcareous, bituminous shale. - some pyritized fossils. - light grey-brown limestone bed @ 43.08 – 43.09 m. - very gradational basal contact – placed transition to dark brown limestone.

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
5	~43.20	46.47	Lindsay Formation - Collingwood Mb.	Limestone and Shale: dark brown to black, bituminous, very fine-grained limestone and black bituminous shale. - massive texture – less fissile than unit 4 (above). - thin bioclastic fossiliferous beds, especially toward base. - some pyrite – blebs and pyritized fossils. - 3 sub-vertical fractures, approximately 2 cm apart, and filled with calcite (< 2 mm) @ 43.75 – 44.56 m.
6	46.47	47.09	Lindsay Formation - Collingwood Mb.	Bituminous limestone: dark brown-black, very fine-grained, bituminous limestone, with thin, minor, lighter fossiliferous interbeds. - basal 10 cm is greenish (gradational characteristic into lower member). - sharp basal contact with light grey limestone; ~ 1 cm relief on contact.
7	47.09	47.68	Lindsay Formation – lower member	Limestone and shale: sparsely fossiliferous, light grey, very fine- to fine-grained limestone, with dark green-grey, slightly bituminous shale interbeds. - top bed (~ 12 cm thick) is fine-grained, sparsely fossiliferous, grey limestone, with diffuse upper and lower contacts. - thick shale bed with fine fossils at 47.23 – 47.47 m. - gradational basal contact.
8	47.68	51.46 (end of hole)	Lindsay Formation – lower member	Limestone and minor shale: typical nodular fossiliferous limestone, with dark green-grey shale interbeds. - limestone ranges from wackestone to bioclastic packstone. - shale typically contains fine fossil fragments. - thicker shale beds at: 49.96 – 50.08 m; 50.86 – 59.94 m; 51.11 – 51.15 m.

Borehole #: RR-3	Location: Rouge River Valley UTM co-ordinates: 648244.2 mE 4852823.4 mN
Date Drilled: April 13 – 17, 2000	Date Logged: May 10, 2000
Drilled by/for: Ontario Power Generation	Logged by: Derek Armstrong (OGS)
Collar Elevation: 84.50 m	Total Depth: 51.42 m

Lithologic Unit Descriptions:

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
0	0	4.32	Quaternary	Overburden – not sampled.
1	4.32	15.32	Blue Mountain	Shale: green-grey shale, with thin dark grey shale interbeds. - top 50 cm is weathered and clayey. - Some thin clayey seams below 50 cm. - dark grey beds up to 20 cm thick, but most are less than 5 cm. - ground core @ 7.30 – 7.85 m (not missing much).
2	15.32	35.20	Blue Mountain	Shale: interbedded grey and dark grey shale. - thick dark grey shale beds at: 15.32 – 15.73 m; 16.45 – 17.42 m; 24.33 – 25.05 m; 30.48 – 31.08 m; 34.55 – 35.20 m. - sub-vertical calcite-filled fractures at: 27.00 – 27.36 m; 32.37 – 33.80 m.
3	35.20	41.38	Blue Mountain	Shale: green-grey shale, with minor, thin, dark grey shale interbeds. - dark beds are slightly calcareous. - base placed at top of thick dark grey shale bed; but base is gradational as thin light shale beds persist below. - sub-vertical calcite-filled fractures at 37.06 – 38.87 m.

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
4	41.38	~43.20	Blue Mountain	Shale and limestone: dark grey-black calcareous, bituminous shale and limestone. - some faintly laminated thin, lighter beds. - fossils are mostly flattened nautiloids(?). - slightly less calcareous than unit 5. - very gradational basal contact – placed at downward transition to browner limestone.
5	~43.20	46.42	Lindsay Formation - Collingwood Mb.	Limestone: dark brown to black, bituminous, very fine-grained limestone. - some thin, light brown-white, bioclastic hash beds. - base sharp at top of fossiliferous bed.
6	46.42	46.86	Lindsay Formation - Collingwood Mb.	Bituminous limestone: dark brown-black, very fine-grained, bituminous limestone, with thin, minor, light brown, bioclastic fossiliferous interbeds. - sharp basal contact at top of fine-grained greenish grey limestone (some gradational characteristics toward base - lighter colour).
7	46.86	47.42	Lindsay Formation – lower member	Limestone and shale: sparsely fossiliferous, light grey, very fine- to fine-grained limestone, with dark green-grey to black, slightly bituminous shale interbeds. - limestone beds are 7 cm, 11 cm, 19 cm and 9 cm thick. - shale beds up to 4 cm thick. - fine fossil fragments throughout, typically in shale beds or at bed contacts. - sub-vertical fracture in basal bed.
8	47.42	51.42 (end of hole)	Lindsay Formation – lower member	Limestone and minor shale: same as other holes. - very thin calcarenite bed at top and at 51.10 – 51.11 m. - 3 shale beds at 48.48 – 48.70 m - 1 shale bed at 48.85 – 48.89 m. - 2 shale beds at 51.00 – 51.10 m. - 4 cm long vertical fracture, filled with coarse calcite (calcarenite?) in limestone bed at 47.64 m.

Borehole #: RR-4	Location: Rouge River Valley UTM co-ordinates: 648200.9 mE 4852747.2 mN
Date Drilled: March 30 – April 4, 2000	Date Logged: May 9, 2000
Drilled by/for: Ontario Power Generation	Logged by: Derek Armstrong (OGS)
Collar Elevation: 84.64 m	Total Depth: 51.47 m

Lithologic Unit Descriptions:

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
0	0	2.60	Quaternary	Overburden – not sampled. note: top of bedrock incorrectly marked in core box.
1	2.60	17.38	Blue Mountain	Shale: green-grey shale, with sparse thin dark grey shale interbeds. - grey shale is weathered locally – especially in upper 3 m. - local thin clay seams (e.g., @ 4.3 – 4.33 m). - dark grey beds less than 10 cm thick and less than 10% of unit. - sharp basal contact, taken at top of thick dark grey shale bed.
2	17.38	36.19	Blue Mountain	Shale: interbedded grey and dark grey-black shale (approx. equal amounts overall). - dark beds generally > 10 cm, and some up to 1 m thick. - thick dark grey shale beds at: 17.38 – 17.33 m; 23.05 – 23.64 m; 25.30 – 26.23 m; 35.52 – 36.19 m. - thin grey clayey seams at: 21.44 – 21.45 m; 21.65 – 21.66 m. - sharp base at base of lowest thick dark grey shale bed.
3	36.19	42.87	Blue Mountain	Shale: grey shale, with minor, thin, dark grey shale interbeds. - less than 10% dark grey-black shale beds.
4	42.87	43.94	Blue Mountain	Shale: interbedded dark brown-grey calcareous shale and grey shale. - top 65 cm is dark bed. - thin light bed at 43.89 m looks similar to bed at 43.15 m in drill hole RR #5. - gradational basal contact.

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
5	43.94	46.35	Lindsay Formation - Collingwood Mb.	Limestone: dark grey-brown to black, bituminous, very fine-grained limestone. - sparse, very thin, light brown-white, bioclastic shelly beds. - sparse pyrite and/or pyritized fossils. - browner colour with depth. - very gradational base.
6	46.35	47.88	Lindsay Formation - Collingwood Mb.	Bituminous limestone: dark brown-black, very fine-grained, bituminous limestone, with thin, light brown-white, bioclastic fossiliferous interbeds. - fossiliferous interbeds increase in abundance with depth. - thicker (up to 4 cm) fossiliferous beds begin at 47.42 m. - sharp basal contact has a few cm relief over irregular limestone bed.
7	47.88	48.40	Lindsay Formation – lower member	Limestone and shale: sparsely fossiliferous, grey, fine-grained limestone, with thin shale interbeds and partings. - top limestone bed is 13 cm thick and is irregularly mottled. - next limestone bed is tabular and 16 cm thick. - basal 7 cm is dark green-grey shale bed.
8	48.40	51.47 (end of hole)	Lindsay Formation - lower member	Limestone and minor shale: nodular, fine-grained, grey fossiliferous limestone, with shaly partings and thin shale interbeds. - some beds non-fossiliferous and thicker. - thin shale interbeds at: 49.89 – 49.94 m; 49.97 – 49.99 m.

Borehole #: RR-5	Location: Rouge River Valley UTM co-ordinates: 648200.9 mE 4852769.3 mN
Date Drilled: April 25 – 28, 2000	Date Logged: May 10, 2000
Drilled by/for: Ontario Power Generation	Logged by: Derek Armstrong (OGS)
Collar Elevation: 83.97 m	Total Depth: 50.90 m

Lithologic Unit Descriptions:

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
0	0	2.60	Quaternary	Overburden – not sampled.
1	2.74	15.52	Blue Mountain	Shale: green-grey shale, with thin dark grey shale interbeds. - dark grey beds up to 13 cm thick, but typically less than 5 cm thick. - thin, horizontal, grey-green, clayey seams and thicker clayey zones (up to 10 cm), common down to approx. 7.5 m – clayey seams continue down into unit 2. - basal contact sharp at top of thick dark shale bed.
2	15.52	35.35	Blue Mountain	Shale: interbedded grey and dark grey-black shale. - grey beds up to 18 cm thick but typically less than 10 cm thick. - thick dark shale beds at: 15.52 – 15.94 m; 16.91 – 17.63 m; 24.42 – 25.36 m; 30.59 – 31.19 m; 34.66 – 35.35 m. - mostly green with thin (< 6 cm), sparse dark beds at 19.94 – 21.04 m. - base sharp at base of lowest thick dark shale bed.
3	35.35	41.69	Blue Mountain	Shale: green-grey shale, with, thin, dark grey shale interbeds. - mainly green-grey shale with thin dark beds (< 13 cm, but most < 5 cm thick). - gradational base.

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
4	41.69	43.93	Blue Mountain	Shale: dark grey-brown to black, very calcareous, bituminous shale. - some pyrite blebs (e.g., 42.32 m) - thin (1 cm) light brown limestone bed with scoured base at 43.15 m - looks similar to bed at 43.89 m RR #4. - gradational basal contact – contact taken at transition between black and underlying brown unit.
5	43.93	46.66	Lindsay Formation - Collingwood Mb.	Limestone: dark brown to black, bituminous, very fine-grained limestone, with minor thin white to light brown, fossiliferous beds. - sharp base at top of thicker white to light brown fossiliferous bed.
6	46.66	47.12	Lindsay Formation - Collingwood Mb.	Limestone: interbedded dark brown-black, very fine-grained, bituminous limestone and light brown-white fossiliferous, bioclastic limestone. - fossiliferous bioclastic beds made up mostly of fine fossil debris (i.e., hash beds). - 4 cm thick fossiliferous bed at top. - mostly very fossiliferous bioclastic limestone in dark brown-black limestone at 46.92 – 47.12 m - bedding in basal 5 cm is @ 30 degrees off horizontal – indicates irregular basal contact. - sharp basal contact.

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
7	47.12	47.84	Lindsay Formation – lower member	Limestone and shale: sparsely fossiliferous, grey, fine-grained limestone, with thin, dark green-grey shale interbeds and partings. - limestone beds are tabular to large nodular. - unit is generally less fossiliferous than underlying unit. - internal stratigraphy is as follows (in descending order): 25 cm limestone, 4 cm shale, 4 cm limestone, 13 cm shale, 13 cm limestone. - gradational basal contact, taken at top of small nodular limestone; increase in fossil content starts lower down at 48.20 m.
8	47.84	50.90 (end of hole)	Lindsay Formation - lower member	Limestone and shale: nodular, fine-grained, grey fossiliferous limestone, with green-grey shaly partings and thin shale interbeds. - some sparsely fossiliferous limestone beds. - some argillaceous, fossiliferous limestone beds. - shale bed at: 49.15 – 49.25 m. - 5 cm long, v-shaped, vertical fracture at top of topmost limestone bed; filled with coarse calcite (+ dolomite? + gypsum?).

Borehole #: RR-6	Location: Rouge River Valley UTM co-ordinates: 648220.4 mE 4852824 mN
Date Drilled: April 18 – 20, 2000	Date Logged: May 10, 2000
Drilled by/for: Ontario Power Generation	Logged by: Derek Armstrong (OGS)
Collar Elevation: 85.25 m	Total Depth: 51.50 m

Lithologic Unit Descriptions:

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
0	0	4.14	Quaternary	Overburden – not sampled.
1	4.14	16.75	Blue Mountain	Shale: green-grey shale, with thin dark grey shale interbeds. - dark grey beds up to 15 cm thick, but typically less than 5 cm thick. - thin, horizontal, grey-green, clayey seams (e.g., 12.67 – 12.69 m) not as abundant as in RR-5; persist down into down into unit 2. - basal contact sharp at top of 38 cm thick dark grey shale bed.
2	16.75	36.25	Blue Mountain	Shale: interbedded grey and dark grey-black shale. - some dark beds up to 1 m thick. - thick dark shale beds at: 17.48 – 18.44 m; 23.15 – 23.77 m; 25.30 – 26.25 m; 31.49 – 32.09 m; 35.58 – 36.25 m. - base sharp at base of lowest thick dark shale bed.
3	36.25	42.94	Blue Mountain	Shale: green-grey shale, with thin (< 10 cm), dark grey shale interbeds. - base is relatively sharp at top of dark brown-black shale.

Unit #	Depth Top	Depth Bottom	Formation – Member	Description
4	42.94	44.10	Blue Mountain	Shale: dark grey-brown to black, calcareous, bituminous shale and limestone. - variable calcareous content (some black shale near base is non-calcareous). - some pyrite – typically coating fossils; rare nodule. - thin (1 cm) light brown limestone bed with scoured base at 43.96 m (see RR-5 and RR-4). - gradational basal contact – placed at base of black slightly calcareous shale.
5	44.10	47.80	Lindsay Formation - Collingwood Mb.	Limestone: dark brown to black, bituminous, very fine-grained limestone, with sparse, thin white to light brown, fossil hash beds. - sharp base at top of thicker white to light brown fossiliferous bed.
6	47.80	48.02	Lindsay Formation - Collingwood Mb.	Limestone: interbedded light brown-white, very fossiliferous, bioclastic limestone and dark brown-black, very fine-grained, bituminous limestone. - 3 cm thick fossiliferous bed at top. - base sharp at undulatory contact with sparsely fossiliferous limestone.
7	48.02	48.36	Lindsay Formation – lower member	Limestone and shale: sparsely fossiliferous, grey, fine-grained limestone, with thin, dark green-grey, slightly bituminous, locally fossiliferous shale interbeds and partings. - limestone beds 8 to 13 cm thick. - shale beds 5 to 6 cm thick. - basal contact (arbitrarily?) placed at base of thin fossiliferous bioclastic bed.
8	48.36	51.50 (end of hole)	Lindsay Formation - lower member	Limestone and shale: nodular limestone, with shaly partings and thin shale interbeds and argillaceous nodular limestone. - same as in other cores. - shale beds at: 48.45 – 45.83 m; 48.70 – 48.74 m.

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	.0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.